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OFFICE OF NAVAL RESEARCH

END-OF-YEAR REPORT
June 1, 1989 - May 31, 1990

PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS/STUDENTS

Contract No. NOOO14-83-K-0450

Principal Investigators:

Alan J. Heeger

Fred Wudl

Paul Smith

Institute for Polymers and Organic Solids
University of California, Santa Barbara
Santa Barbara, CA 93106



Submitted May, 1990

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Part I

a. Papers Submitted to Refereed Journals (and not yet published)

Highly conductive and Stiff Fibers of Poly(2,5-dimethoxy-p-phenylenevinylene) Prepared from Soluble Precursor Polymer, S. Tokito, P. Smith and A. J. Heeger (submitted to Polymer).

The Synthesis and Characterization of Dimethyl Diacetoxypseudocane and Related Compounds, R. H. Jacobson and F. Wudl (submitted to Journal of Organic Chemistry).

b. Papers Published in Refereed Journals

Mechanical and Electrical Properties of poly(2,4-thienylenevinylene) fibers, S. Tokito, P. Smith and A.J. Heeger, Synth. Met. 36, 185 (1990).

Photoinduced Localized Charged Excitations in Polyaniline, Y. H. Kim, C. Foster, J. Chiang and A. J. Heeger, Synth. Metals 26, 49 (1988).

Spectroscopic Studies of Polyaniline in Solution and in Spin-Cast Films, Y. Cao, P. Smith and A. J. Heeger, Synth. Metals 32, 262 (1989).

Photogenerated Carriers in $\text{La}_2\text{Cu}_3\text{O}_4$, $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ and $\text{Tl}_2\text{Ba}_2\text{Ca}_{(1-x)}\text{Gd}_x\text{Cu}_x\text{O}_8$: Polarizability-Induced Pairing of Polarons, C. M. Foster, A. J. Heeger, Y. H. Kim and G. Stucky, Synth. Metals 33, 171 (1989).

Infrared-Active Vibrational Modes of Heavily Doped "Metallic" Polyacetylene, Y. H. Kim and A. J. Heeger, Phy. Rev. B 40 (12), 8393 (1989).

Photoinduced Self-Localized Polarons in $\text{Tl}_2\text{Ba}_2\text{Ca}_{(1-x)}\text{Gd}_x\text{Cu}_2\text{O}_8$: A Proposal for Van Der Waals Pairing, C. M. Foster, A. J. Heeger and G. Stucky, Solid State Commun. 71 (11), 945 (1989).

X-Ray Scattering from Crystalline Polyaniline, Y. B. Moon, Y. Cao, P. Smith and A. J. Heeger, Polymer Commun. 30 196 (1989).

c. Books (and Sections thereof) Submitted for Publication

None

d. Books (and Sections thereof) Published

Fibers of Conducting Polymers: High Electrical Conductivity Combined with Attractive Mechanical Properties, Mat. Res. Symp. Proc. Vol. 173 (Materials Research Society, 1990) p. 269.

e. Technical Reports Published
None

f. Patents Filed
None

g. Patents Granted
None

h. Invited Presentations at Topical or Society Conferences

A. J. Heeger - June, 1989 - Invited Lecture
"Lower Dimensional Systems and Molecular Devices", Poros Island,
Greece

A. J. Heeger - June, 1989 - Invited Lecture
SAMPE Conference "Electronic Materials and Processes", Los Angeles

A. J. Heeger - July, 1989 - Invited Lecture
International Conference: Materials and Mechanisms of
Superconductivity High-Temperature Superconductors (M²S-HTSC
Conference), Stanford University, Palo Alto, CA

A. J. Heeger - September, 1989 - Invited Lecture
NATO Advanced Workshop on "Conjugated Polymeric Materials:
Opportunities in Electronics, Optoelectronics, and Molecular
Electronics", Mons, Belgium

A. J. Heeger - September, 1989 - Invited Lecture
"Charge Transfer in Polymeric Systems" (Faraday Discussion), Oxford,
England

A. J. Heeger - September, 1989 - Invited Lecture
AFOSR Review, Long Beach, California

A. J. Heeger - October, 1989 - Invited Lecture
Almaden Symposium
IV International Conference on Unconventional Photoactive Solids (UPS)
San Jose, California

A. J. Heeger - October, 1989
ONR Chemistry Division Polymer Program Discussion
Naval Research Laboratory, Washington, D.C.

A. J. Heeger - October, 1989
3rd Symposium on Electroresponsive Molecular and Polymeric Systems
Brookhaven National Laboratory, Upton, Long Island, New York

A. J. Heeger - November 27-December 2, 1989 - Invited Lecture
MRS Symposium "Electrical Optical and Magnetic Properties...", Boston

A. J. Heeger - December, 1989 - Invited Lecture
"Conducting Polymers: Recent Progress and Future Prospects", Maui

A. J. Heeger - December, 1989 - Invited Lecture
"Nonlinear Optical Effects on Conjugated Polymers", Honolulu, Hawaii

A. J. Heeger - February, 1990
Dupont Central Research Division - Seminar, Wilmington, Delaware

A. J. Heeger - February, 1990
Princeton University - Solid State Seminar, New Jersey

A. J. Heeger - March, 1990
NSF Workshop on Group Grants, Washington, D.C.

March, 1990

A. J. Heeger, F. Wudl, D. Pearson, P. Smith, H. Schdmit, P. Pincus -
APS Short Course "Conducting Polymers: Electronic and Optical
Properties"
American Physical Society, Anaheim, California

A. J. Heeger - March, 1990
Lecture Trip
March 26 - Iowa State University - Seminar
March 27 - Center for Computational Sciences, Univ. of Kentucky -
Seminar

A. J. Heeger - April, 1990 - Invited Lecture
MACHTEC 90, Dresden, East Germany

A. J. Heeger - April, 1990 - Invited Lecture
Rolduc Polymer Meeting, Netherlands

A. J. Heeger - May, 1990
UCLA, Chemical Physics - Invited Seminar

A. J. Heeger - May, 1990 - Invited Lecture
European Physical Society Workshop on the Science and Applications
of Conducting Polymers, Lufthus, Norway

F. Wudl - June, 1989 - Invited Lecture
American Chemical Soc. regional meeting
Materials Chemistry Symposium, Reno, Nevada

F. Wudl - August 1989 - Invited Lecture
12th Int'l Congress of Heterocyclic Chemistry, Jerusalem, Israel

F. Wudl - August 27-31, 1989 - Invited Lecture
1st ISSP International Symposium on the Physics & Chemistry of
Organic Superconductors, Japan

F. Wudl - September 1989
NATO meeting, Mons, Belgium

F. Wudl - November, 1989 - Invited Lecture
Materials Research Society meeting, Boston

F. Wudl - November 1989 - Invited Seminar, UC Berkeley

F. Wudl - March, 1990 - Invited Lecture
"Frontiers in Chemistry" series - "Novel Conductors"
Case Western Reserve University, Cleveland, Ohio

F. Wudl - April, 1990 - Invited Lecture
American Chemical Society meeting, Boston, MA

F. Wudl - May 2, 1990 - Invited Seminar
3M Company, St. Paul, Minnesota

F. Wudl - May 3, 1990 - Invited Seminar
University of Wisconsin at Madison

F. Wudl - May, 1990
First New Industrial Chemistry and Engineering Conference
"Future Directions in Polymer Science & Technology"
Keystone, Colorado

F. Wudl - May, 1990
International Conference on Organic Superconductors, Stanford
University, Stanford, California

P. Smith - Award Lecture
Invited Lecture
Royal Dutch Chemical Society
Maastricht, Holland

P. Smith - October 28, 1989, Invited Lecture
Outstanding Achievement Award of the Fiber Society of America
Chapel Hill, NC

P. Smith - April, 1990 - Invited Lecture
Rolduc Polymer Meeting, Netherlands

P. Smith - May, 1990 - Invited Lecture
European Physical Society Workshop on the Science and Applications
of Conducting Polymers, Lufthus, Norway

P. Smith - October-November 1989
Lecture Series, Japan

P. Smith - October 1989 - Invited Lecture
Polymer Society of Japan, Kyoto, Japan

D. McBranch - June, 1989 - Invited Lecture
NATO Advanced Study Institute, Mons, Belgium

C. Foster - July, 1989 - Invited Lecture
M²S-HTSC Conference, Stanford University, Stanford, Calif.

C. Foster - September, 1989 - Invited Lecture
U.S.-Japan Conference on "Atomic Processes Induced by Electronic
Excitation in Non-Metallic Solids", Japan

i. Contributed Presentations at Topical or Scientific Conferences

March 1990 - Contributed papers
American Physical Society meeting Anaheim, California
A. J. Heeger "
Y. Cao "
D. Moses "
D. McBranch "
G. Yu "
C. M. Foster "
D. Mihailovic "

j. Honors/Awards/Prizes

A. J. Heeger - John Scott Award (Medal and Premium) for 1989

F. Wudl - Elected Fellow of the American Association for the
Advancement of Science

P. Smith - Gold Medal of the Royal Dutch Chemical Society

P. Smith - Outstanding Achievement Award of the Fiber Society of
America

k. Number of Graduate Students Receiving at least 25% Support on ONR
grant or contract

Total: 2 Minorities: 0 Asian: 0

- i. Number of Postdoctorals Receiving at least 25% Support on ONR grant or contract

Total 4

Minorities 3

Asian: 3

- m. Other Funding - A. J. Heeger, Fred Wudl and Paul Smith (see attached)

CURRENT SUPPORT - A. J. HEEGER

Principal Investigator	Source of Support	Project Title	Award Amount	Period Covered by Award	% of Effort Committed to Effort	Location Research	Co-PI
Current Support A.J. Heeger	AFOSR	"Oriented Electro/Optical Polymers Through In-Situ Chemistry During Gel Processing: A Research Opportunity"	\$110,000 ^a	9/15/89-9/14/90	10	UCSB	P. Smith F. Wudl
	NSF-MRG	"Oriented Conducting Polymers: Solution Processing and Characterization"	\$ 90,000 ^b	3/1/89-2/28/90	10	UCSB	P. Pincus P. Smith F. Wudl D. Pearson
	ONR	"Nonlinear Optical Properties of Semi-conducting Polymers"	\$101,477	6/1/89-5/30/90	5	UCSB	D. Moses
	ONR	"Program for Research on Conductive Polymers"	\$ 80,000 ^c	10/1/89-9/30/90	5	UCSB	F. Wudl P. Smith
	Showa Denko	"Cooperative Program in Polymers and Organic Solids"	\$ 50,000 ^d	10/1/89-9/30/90	5	UCSB	F. Wudl
	EPRI	"Toward Improvements in the Current Carrying Capability of Conducting Polymers"	\$ 75,541	5/15/89-12/31/89	5	UCSB	
	NSF	"Program of Cooperative Research on Conjugated Polymers With Prof. J.-L. Brédas (Chemistry, University of Mons, Belgium)"	\$ 1,500 ^e	11/1/89-10/31/90	1	UCSB	Wudl

CURRENT SUPPORT - FRED WUDL

Principal Investigator	Source of Support	Project Title	Award Amount	Period Covered by Award	% of Effort Committed to Project	Location Research	Co-PI
Current Support Fred Wudl	NSF	"Oriented Conducting Polymers: Solution Processing and Characterization"	\$ 35,000 ^a	3/15/89-3/14/90	3	UCSB	P. Pincus P. Smith A.J. Heeger D. Pearson
	Showa Denko	"Cooperative Program in Polymers and Organic Solids"	\$ 42,000 ^b	10/1/89-9/30/90	5	UCSB	A.J. Heeger
	AFOSR	"Oriented/Optical Polymers Through In Situ Chemistry During Gel Processing..."	\$ 50,000 ^c	9/15/89-9/14/90	2	UCSB	P. Smith A. J. Heeger
	ONR	"Program for Research in Conducting Polymers"	\$ 60,000 ^d	10/1/89-9/30/90	5	UCSB	A. J. Heeger P. Smith
	NSF	"Synthesis of New Organic Materials: Ferromagnetic Organic Metals, Cyanovinyl Acceptors and Oxydonors"	\$93,000 ^e	4/1/89-3/31/90	15	UCSB	
	NSF	"High Strength Materials, Polymers for Nonlinear Optics and New Electrically Conducting Polymers"	\$ 89,000	8/1/89-7/31/90	15	UCSB	
	NSF	"Molecular Atoms (Heterospherophanes)"	\$157,000	9/1/89-8/31/91	10	UCSB	P. Pincus
	NSF	"Program of Cooperative Research on Conjugated Polymers With Prof. J.-L. Brédas (Chemistry, University of Mons, Belgium)"	\$ 1,500 ^f	11/1/89-10/31/90	1	UCSB	Wudl

CURRENT SUPPORT - PAUL SMITH

Principal Investigator	Source of Support	Project Title	Award Amount	Period Covered by Award	% of Effort Committed to Effort	Location Research	Co-PI
Current Support Paul Smith	ARO	"Tractable High Performance Polymers"	\$ 25,000 ^a	03/01/89-02/28/90	10	UCSB	A.J. Heeger D. Pearson H. Schmidt
	AFOSR	"Oriented Electro/Optical Polymers Through In-Situ Chemistry During Gel Processing: A Research Opportunity"	\$100,000 ^b	09/15/88-09/14/89	10	UCSB	A.J. Heeger F. Wudl
	NSF-MRG	"Oriented Conducting Polymers: Solution Processing and Characterization"	\$ 90,000 ^c	03/15/88-08/31/89	10	UCSB	P. Pincus D. Pearson F. Wudl A.J. Heeger
	ONR	"Program for Research on Conductive Polymers"	\$ 70,000 ^d	10/01/88-09/30/89	5	UCSB	F. Wudl A.J. Heeger
	DSM	Research Gift	\$100,000	1988-present			
	DuPont	Research Gift	\$ 60,000	1987-present			

Part II

a. Principal Investigators

Alan J. Heeger
Fred Wudl
Paul Smith

- b. Alan J. Heeger (805) 961-3184
Fred Wudl (805) 961-3755
Paul Smith (805) 961-8104

c. Dr. Kenneth Wynne (ONR - Chemistry)

d. Brief (100-200 words) Description of Project

This is an interdisciplinary project focused on the fundamental chemistry, physics and materials science of conducting polymers in the context of the novel electronic phenomena associated with this emerging class of materials. The full range of research is involved: synthesis and characterization of new conducting polymers, processing directed toward the achievement of chain oriented and chain extended materials with a goal of striving for intrinsic electronic and optical properties, and physical measurements directed at characterizing these electronic and optical properties and of identifying the basic physical mechanism involved in these phenomena.

e. Significant Results During Last Year

Through studies of the electrical and mechanical properties of fibers of poly(thienylenevinylene) and poly(dimethoxyphenylenevinylene) we discovered that the electrical and mechanical properties improve together and in a correlated manner as the degree of chain extension and chain alignment are improved through tensile drawing. The result is conducting polymers with a remarkable combination of properties: high electrical conductivity, high strength and high modulus --- a combination that was thought by many to be impossible. The basic theoretical origin of this combination of properties has been identified in terms of coherent secondary bonds (interchain coupling) in chain extended and chain aligned systems. The conclusion is that this correlation between electrical and mechanical properties is intrinsic and can be expected to be a general feature of the class of conducting polymer materials.

f. Brief (100-200 words) Summary of Plans for Next Year's Work

Recent progress in our laboratories with blends of conducting polymers and traditional polymers has opened the way to a broad based study of such systems. In addition to the obvious advantages of such blends (one can design materials to have unique combination of properties associated with the two constituents), there are two specific advantages of blending conducting polymers:

(1) The use of blends cuts down on the volume fraction of the expensive component; i.e. the conductive polymer. Thus for applications, blending offers the promise of major cost advantages.

(2) The use of blends "self-encapsulates" the conducting polymer. Since environmental stability remains a serious issue, this self-encapsulation can be an important feature.

During the next year we will use the soluble conducting polymers (soluble PPV derivatives, soluble P3AT's, soluble polyaniline, etc) and precursor polymers of conducting polymers to develop and process such blends.

g. List of Names of Graduate Students and Postdoctorals Currently Working on Project

Braun, David
Foster, Christopher
Karl Voss
Moses, Daniel (Associate Research Physicist)
Zhang, Chi
Liou, Kwangkyoung
Fite, Christian
Tokito, Shizuo